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Volume 9 July 15, 1959 No. 3

TWO NEW SALMONELLA TYPES: SALMONELLA HOLCOMB AND SALMONELLA NEWROCHELLE

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The two serotypes to be described were received for confirmation from the New York State Department of Health. Salmonella newrochelle was isolated in the New Rochelle Hospital by Dr. W.C. Schraft and Salmonella holcomb in the Rochester Health Laboratory by Dr. H. R. Morgan. Both were derived from the stools of cases of enteric infection in man. The person from whom S. newrochelle was isolated was an adult male who was affected with diarrhea in French Equatorial Africa two months previously and who had experienced bouts of fever and diarrhea since that time.

The two cultures possessed cultural characteristics typical of the genus Salmonella and results obtained in biochemical tests with them were identical. The organisms failed to produce indol, were methyl red positive and Voges-Proskauer negative and grew readily in Simmons' citrate medium. Hydrogen sulfide was produced, but the bacteria failed to hydrolyze urea, to liquefy gelatin or to grow in KCN medium. The lysine decarboxylase test was positive and mucate, D-tartrate and citrate were utilized when tested by the method of Kauffmann and Petersen (1956). Malonate was not attacked. The cultures promptly produced acid and gas from glucose, arabinose, rhamnose, xylose, maltose, trehalose, mannitol, dulcitol, and sorbitol. Lactose, sucrose, raffinose, salicin, inositol, and adonitol were not attacked.

S. holcomb was a member of Salmonella group C_2, was agglutinated to the titre of, and in absorption tests removed all agglutinins from, Salmonella newport O (6,8) serum. The H antigens of S. holcomb were diphasic and phase 1

was agglutinated to the titre of Salmonella bredeney, phase 1 (1, v) serum. It was agglutinated actively by single factor v serum but not by sera for factors w, z_{13}, or z_{28}. In absorption tests it reduced the titre of S. bredeney, phase 1 serum from 4000 to 100. After absorption the serum no longer agglutinated phase 1 of Salmonella worthington (1, w), Salmonella uganda (1, z_{13}), or Salmonella javiana (1, z_{28}). Phase 2 of S. holcomb was agglutinated to the titre of Salmonella abortus equi H (e, n, x) serum and in absorption tests removed all agglutinins from the serum. S. holcomb was assigned the antigenic formula 6, 8:1, v-e, n, x.

S. newrochelle was a member of Salmonella O group E_1. It was agglutinated to the titre of, and absorbed all agglutinins from Salmonella anatum O (3, 10) serum. The H antigens were diphasic and phase 1 was agglutinated to the titre of, and absorbed all H agglutinins from, Salmonella thompson, phase 1 (k) serum. Phase 2 was agglutinated to the titre of Salmonella worthington, phase 2 (1, w) serum and by single factor w serum but not by sera for factors v, z_{13}, or z_{28}. In absorption tests phase 2 of S. newrochelle exhausted S. worthington, phase 2 serum of H agglutinins. It was assigned the antigenic formula 3, 10: k-1, w.

SUMMARY

Two new Salmonella serotypes are described: S. holcomb (6, 8: 1, v-e, n, x) and S. newrochelle (3, 10: k-1, w). Both were isolated from cases of enteric infection in man.

REFERENCE

Kauffmann, F. and A. Petersen. 1956. The biochemical group and type differentiation of Enterobacteriaceae by organic acids. Acta path. et microbiol. Scand. 38:481-491.

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A NEW SALMONELLA TYPE: SALMONELLA ESCANABA (6, 7: k-*e*, n, z_{15})

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Agricultural Research Service
U.S. Department of Agriculture and

Communicable Disease Center
Public Health Service, U.S. Department
of Health, Education and Welfare,
Atlanta, Ga.

Salmonella escanaba was forwarded for confirmation by Mr. Arnold Juenker of the Michigan State Department of Health, who had correctly identified the antigens of the organism and recognized it as an undescribed serotype. The organism was isolated from the stool of an asymptomatic adult female who had diarrhea one month previously.

In its cultural and biochemical aspects the organism was a typical member of the Salmonella group which failed to form indol, was methyl red positive and Voges-Proskauer negative, and grew readily in Simmons' citrate medium. Hydrogen sulfide was produced but the bacterium failed to hydrolyze urea, to liquefy gelatin, or to grow in KCN medium. The lysine decarboxylase test was positive and mucate, D-tartrate, and citrate were utilized when tested by the method of Kauffmann and Petersen (1956). Malonate was not attacked. Acid and gas were produced promptly from glucose, arabinose, xylose, rhamnose, maltose, trehalose, dulcitol, inositol, mannitol, and sorbitol. Lactose, sucrose, raffinose, salicin, and adonitol were not attacked.

The organism was a typical member of Salmonella O group C_1, was agglutinated to the titre of Salmonella thompson O (6, 7) serum, and in absorption tests removed all agglutinins from the serum. The H antigens were diphasic and phase 1 was agglutinated to the titre of S. thompson, phase 1 (k) serum and in absorption tests removed all agglutinins from the serum. Phase 2 was agglutinated actively by e, n, x and e, n, z_{15} sera and by single factor z_{15} serum but not by x serum. In absorption tests it removed all H agglutinins from e, n, z_{15} serum prepared from a sucrose

fermenting organism having the formula 4, 12: e, n, z_{15} (Edwards, 1950). The organism was assigned the antigenic formula 6, 7: k-e, n, z_{15} .

SUMMARY

A new Salmonella type, S. escanaba (6, 7: k-e, n, z_{15}) is described. It was isolated from the stool of an asymptomatic adult female who had diarrhea one month previously.

REFERENCES

Edwards, P. R. 1950. Unusual antigenic variation in an enteric bacterium. Proc. Soc. Exp. Biol. and Med. 74:471-474.

Kauffmann, F. and A. Petersen. 1956. The biochemical group and type differentiation of Enterobacteriaceae by organic acids. Acta path. et. microbiol. Scand. 38; 481-491.

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INTERNATIONAL COMMITTEE ON PHAGE TYPING OF STAPHYLOCOCCI

MINUTES OF SECOND MEETING

The second meeting of the Committee was held at the Karolinska Institute, Stockholm, on August 2nd 1958. The following were present:

Dr. V.D. Allison	Belfast
Dr. J.E. Blair	New York
Professor Dr. H. Brandis	Göttingen, Germany
Dr. E.T. Bynoe	Ottawa
Dr. H. Milch-Bognar	Budapest
Dr. H.P. Pöhn	Göttingen, Germany
Dr. H. Rische	Wernigerode, Germany
Dr. K. Rosendal	Copenhagen
Dr. P.M. Rountree	Sydney, Australia
Professor C. Ruys	Amsterdam
Dr. E. Updyke	Chamblee, U.S.A.
Professor Th. Vogelsang	Bergen, Norway
Dr. R. Wahl	Paris
Dr. G. Wallmark	Stockholm
Dr. R.E.O. Williams	London

1. Dr. J.E. Blair was elected Chairman, and Dr. R.E.O. Williams was elected Secretary to serve until the next meeting of the Committee.

2. Composition of the Committee. After discussion it was agreed that the Committee should ordinarily include only one member from any one country, and that an attempt should be made to include a representative from any country in which phage typing of staphylococci is being carried out. The member should be in a position to represent other workers in his or her country who were using the technique for routine typing purposes. The actual method of selection of the national representative would have to be determined in relation to local organization. If a member of the Committee was unable to attend a meeting, he could send a deputy.

3. It was agreed that the functions of the Committee included

i) Exchange of pertinent information.

ii) Arrangement of tests to compare phage typing results obtained in the different laboratories.

iii) Maintenance of an index of national phage typing laboratories and nomination of a central laboratory to supply material etc. to national laboratories.

A provisional list of national laboratories is appended to these minutes. It was agreed that the Staphylococcus Reference Laboratory, Colindale should continue to serve as the International Reference Centre.

4. Supply of typing phages. It was agreed that all national laboratories should be supplied with new sets of the basic set phages and propagating strains at intervals of about 2 years.

5. Tests of typing. It was agreed that the comparative typing test carried out during 1957 had proved very useful, and ought to be repeated at intervals of about 2 years. It was also recommended that similar tests might be carried out among the laboratories within the various countries.

The Chairman and Secretary were asked to explore the possibility of obtaining funds from the World Health Organization to help with the supply of material to national laboratories and for the periodic international comparisions.

6. Use of calcium in typing media. There was general discussion of the importance of the calcium chloride in typing media. There was general agreement that calcium deficiency was often responsible for failure of some phages, especially 52, 52A etc. to act, but Dr. Wahl stressed the possible dangers of excess calcium and salt.

7. Constitution of the basic set of typing phages. It was agreed to omit phage 70 from the basic set of phages, and to include 80 and 187. The set would thus comprise:

Gp. I	29, 52, 52A, 79, 80
II	3A, 3B, 3C, 55, 71
III	6, 7, 42E, 47, 53, 54, 73, 75, 77
IV	42D
Misc.	187

It was recommended that all laboratories should employ, as a minimum, this set of 21 phages. There was no objection to the use of such additional phages as were found locally useful, but it was desirable that all publications giving the

results of phage typing should include a list of the phages used.

The phage isolated by Dr. Bynoe and Mr. Comtois and referred to by them as 52AV was given the number 82. Phages 81 and 82 could be included in the additional set of phages.

8. Use of non-lysogenic propagating strains. There was discussion of the usefulness of attempting to isolate non-lysogenic variants of the phage propagating strains, but it was felt that insufficient results were yet available to allow a conclusion. Members agreed to keep the Secretary informed of any strains that they isolate or work on, so as to avoid duplication of effort.

9. Interpretation of phage typing results. Dr. Rountree gave a brief account of observations made, in both Sydney and Colindale, on variation of strains of phage type 80 to the pattern 52/52A/80. Apart from this, Dr. Williams has not seen reason to alter the rule offered in the 1952 paper, of requiring 2 strong phage reactions different before concluding that 2 strains had a different origin. There was nevertheless agreement that strains often showed much greater constancy of pattern than was implied in this rule.

Dr. Ruys described the conventions that she had used for deccribing phage typing results. She listed the phage reactions in order of strength and included all the reactions observed. While agreeing that this method had clear advantages, it was generally felt to be too complex for general use.

10. Dr. Bynoe commented on the variation in lytic spectrum in reports from Colindale. Dr. Williams agreed to circulate a note on this subject with the latest recommended data.

List of Active Members, November, 1958

Dr. V.D. Allison, The Laboratories, Belfast City Hospital, Belfast, Northern Ireland.

Dr. J.E. Blair, Dept. of Bacteriology, Hospital for Joint Diseases, Madison Avenue, 123rd Street, New York 35, N.Y., U.S.A.

Dr. E.T. Bynoe, Department of National Health and Welfare, Laboratory of Hygiene, Ottawa, Canada

Dr. M. Eörsi, Staatl. f. Hygiene, Gyáli et 2, Budapest IX, Hungary.
Dr. M. Grigorova, Research Institute of Epidemiology and Microbiology, Bld. VI. Zaimov, 26, Sofia, Bulgaria.*
Professor K. Ishihara, University of Gunma College of Medicine, Maebashi, Japan.*
Dr. J.D. Manning, National Health Institute, 52, Riddiford Street, Wellington, S.I., New Zealand.
Dr. R. Pakula, Państwowy Zakad Higieny Centrala, ul. Chocimska 24, Warsaw, Poland.
Dr. H.P. Pöhn, Hygiene-Institut der Universität, Kreuzbergring 57, Göttingen, Germany.
Dr. M. Popovici, Institut "Dr. I. Cantacuzino", Bukarest, Roumania.
Dr. K. Raška, Státní Zdravotnický Ústav, Šrobárova 48, Prague XII, Czechoslovakia.
Dr. G. Rische, Zentral Laboratorium für Lysotypie beim Bezirks-Hygiene-Institut Wernigerode, Burgstrasse 37, Wernigerode, Germany.
Dr. K. Rosendal, State Serum Institute, Amager Boulevard 80, Copenhagen, Denmark.
Dr. Phyllis Rountree, Fairfax Institute of Pathology, Royal Prince Alfred Hospital, Camperdown, N.S.W., Australia.
Professor A. Charlotte Ruys, University of Amsterdam, Dept. of Bacteriology, Mauritskade 57, (Oosterpark), Amsterdam, Holland.
Dr. R. Skalova, School of Public Health, "Andrija Stampar" University of Zagreb, Mirogojska Cesta 4, Zagreb, Yugoslavia.
Dr. E. Updyke, Streptococcus Laboratory, P.O. Box 185, Chamblee, Georgia, U.S.A.*
Professor Th. M. Vogelsang, Gade's Institute, Bergen, Norway.
Dr. R. Wahl, Institute Pasteur, 25 rue du Docteur Roux, Paris XV, France.
Dr. G. Wallmark, State Bacteriological Laboratory, Box 764, Stockholm 1, Sweden.
Dr. R.E.O. Williams, Staphylcoccal Reference Laboratory, Colindale Avenue, London, N.W. 9, England.

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*Added to the Committee since August, 1958.

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INTERNATIONAL BACTERIOLOGICAL NOMENCLATURE COMMITTEE SUBCOMMITTEE ON STREPTOCOCCI AND PNEUMOCOCCI

MINUTES OF SECOND MEETING

1. A meeting of the Subcommittee was held at the Karolinska Institute, Stockholm on August 2nd 1958. The following were present:

Dr. V.D. Allison	Belfast (Chairman)
Dr. B. Eddy	Washington
Dr. R.M. Fry	Cambridge, England
Professor O. Guthof	Köln, Germany
Dr. E. Lund	Copenhagen
Dr. I. Pattison	Compton, England
Dr. M. Plommet	Jouy-en-Josas, France
Professor M. Seelemann	Kiel, Germany
Dr. K. Skadhauge	Copenhagen
Dr. A.W. Stableforth	Weybridge, England
Dr. E. Updyke	Chamblee, U.S.A.
Dr. R. Wahl	Paris
Dr. R.E.O. Williams	London

Apologies for absence were received from Dr. Rebecca Lancefield (New York) and Dr. C. MacLeod (New York).

2. Dr. Allison welcomed the members and referred to the record of the previous meeting, held in Rome in 1953 (see ISC/1).

3. Definition of "Groups" of streptococci. There was extensive discussion of the relative usefulness of serological and physiological methods of identifying groups or species of streptococci. There was general agreement that serological methods were to be preferred, but the description of a new group or species should include physiological as well as serological characterization. No new species could be described without the examination of several independent strains, isolated from different sources separated in time or space. Linguistically at least, it was undesirable to describe a new "group" unless distinct types were represented within it; such description should certainly be provisional in the first place.

The importance of defining technical methods was stressed by several members, but it was not thought practicable to standardize such methods to any great extent.

It was agreed, however, that a standard set of reference strains should be accumulated which could be used for comparison of the results obtained in different laboratories. Later, if found technically possible, reference sets of desiccated preparations of the group carbohydrates, and of group antisera might be made available. The Secretary was asked to get in touch with laboratories holding representative collections of strains and to try, first, to get agreement on a suitable standard set of strains.

4. After discussion it was agreed by those present that the pneumococcus was best regarded as a species within the genus Streptococcus.

5. Type identification of pneumococci. Dr. Lund and Dr. Eddy gave brief accounts of their methods of classifying the types of pneumococci. Dr. Lund and Dr. Eddy were asked to discuss further among themselves and inform the Secretary of any agreement they could reach.

6. Professor Seelemann opened a discussion on the classification of the so-called greening streptococci. After discussion it was agreed that it would be useful to circulate a number of strains to several laboratories interested in this work, to compare the methods used and the diagnosis arrived at, by different workers. The Secretary was asked to arrange this.

7. The Secretary reported the progress of the Panel set up to define a neotype culture for the species Streptococcus agalactiae. It was agreed that, before the strain V8 was accepted, the Panel should be asked again whether another strain, e.g. G. 19 was not preferable since V8 commonly fails to ferment salicin.

8. Dr. Pattison introduced his paper on the nomenclature of S. agalactiae. In the discussion it was emphasized that, in reports on work done with S. agalactiae, it was very important to record the type of the strain used.

9. It was agreed that the type of S. pyogenes known as "Red Lake" should be accepted and given the number 49.

10. After discussion it was agreed that the Subcommittee served a useful purpose. The Secretary was asked to find out whether there were other persons interested in its field who might be invited to serve on the Subcommittee. It was

felt that any member who had taken no part in the Subcommittee's activities since 1953 might be asked whether he wished to continue as a member.

Dr. Allison was asked to continue to serve as the Chairman and Dr. Williams as the Secretary of the Subcommittee until the next meeting.

January, 1959

List of Active Members, January, 1959

Dr. V.D. Allison, The Laboratories, Belfast City Hospital, Belfast, Northern Ireland.

Dr. B. Eddy, National Institute of Health, Bethesda 14, Maryland, U.S.A.

Dr. R.M. Fry, Public Health Laboratory, Tennis Court Road, Cambridge.

Professor O. Guthof, Institute of Hygiene, Köln University, Fürst-Pückler-Strasse 56, Köln-Lindental, Germany.

Professor P. Arne Hansen, Maryland State Board of Agriculture, Live Stock Sanitary Service Laboratory, College Park, Maryland, U.S.A.

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Dr. R. Lancefield, Rockefeller Institute for Medical Research, 66th St. & York Avenue, New York 21, N.Y., U.S.A.

Dr. E.M. Lund, State Serum Institute, Amager Boulevard 80, Copenhagen, Denmark.

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Dr. A.T.R. Mattick, National Institute for Research in Dairying, Shinfield, Reading, Berks.

Dr. G. Mocquot, Station Centrale de Microbiologie et Recherches Laitieres, Jouy-en-Josas, France.

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Dr. R. Pakula, Państwowy Zakład Higieny Centrala, Ul. Chocimska 24, Warsaw, Poland.

Dr. I.H. Pattison, Agricultural Research Council, Field Station, Compton, Newbury, Berks.

Professor M. Seelemann, Institute für Milchhygiene, Hermann Weigmannstr. 3/11, Kiel, Germany.
Dr. K. Skadhauge, State Serum Institute, Amager Boulevard 80, Copenhagen, Denmark.
Dr. A.W. Stableforth, Ministry of Agriculture & Fisheries, New Haw, Weybridge, Surrey.
Dr. E. Updyke, Streptococcus Laboratory, P.O. Box 185, Chamblee, Georgia, U.S.A.
Dr. R. Wahl, Institut Pasteur, 25 rue du Docteur Roux, Paris XV, France.
Dr. R.E.O. Williams, Streptococcus Reference Laboratory, Colindale Avenue, London N.W. 9.

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CONTRIBUTION TO THE TAXONOMIC STUDIES OF SARCINA LUTEA SCHROETER AND SARCINA FLAVA DE BARY

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(With the technical assistance of J. Benešová)

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Taxonomic studies of the genus Sarcina, particularly of the two closely cognate species Sarcina lutea Schroeter and Sarcina flava De Bary, are inadequate in many details. The original concise description of Sarcina lutea (1886) and Sarcina flava (1887) were given under the strong influence of the monomorphic concept of species and were accepted by later authors without any essential emendation that would be of great importance for further taxonomic studies.

The descriptions have been more adequately formulated in Bergey's Manual (1948, 1957) and Krassilnikov's Guide (1949). Recently studies not directly connected with the taxonomy of the aforesaid microorganisms have appeared. These later investigations, especially relating to Sarcina lutea, for example, identify nucleic acid (Dutta and Jones, 1956) and certain carotenoid pigments (Arnaki and Stary, 1952; Miller, 1954; Besborodov, 1956). Mutants of these species were investigated by Witkus (1948) and Bellini (1951). The contributions of these authors, although not primarily aimed at taxonomy [as the recent Aaronson's studies (1956)], nevertheless include results that can be used in the taxonomic studies of the genus Sarcina.

Some authors, e.g. Lehmann and Neumann (1927), have suggested that Sarcina lutea and S. flava might be identical. As a result of this expression of opinion we have undertaken to ascertain the characteristics of the two species, to determine their identity or differences and on the basis of the results obtained to place them correctly in the genus Sarcina.

MATERIAL AND METHODS

In our work we have studied 16 strains of Sarcina lutea

and 28 of S. flava, of these 26 strains were acquired from various collections in Czechoslovakia and abroad, 18 strains were isolated by us from water and air. The list of strains is given in table 1. We have studied morphological, cultural and biochemical characteristics of these cultures. We have

Table 1.

Species	Strain No.	Source of Strain
Sarcina lutea	352, 353, 354, 355	Dr. Stárka, Dept. of
	356	Microbiol., Prague
	357	Biological Institute, Prague
	362	Institute for Fermentation, Osaka, Japan
	336	Dept. of Applied Biology, NRC., Ottawa
	249	Institute of Hygiene, Perugia, Italy
	407, 408, 409	Dept. of Microbiol., Bratislava
	443	Institute of Hygiene, Warsaw
	149, 310, 373	Own isolates
Sarcina flava	268	State Inst. of Public Health, Prague
	358	Dr. Starka, Dept. of Microbiol., Prague
	296	Dept. of Biological Sci., Purdue Univ., USA
	335	Dept. of Applied Biology, NRC., Ottawa
	163, 166, 372, 308	Own isolates
	309, 365, 366, 367	
	368, 369, 370, 371	
	374, 437, 438, 439	
	511, 512, 513, 514	
	515, 516, 517, 518	

used the following methods: Gram's stain as modified by Hucker, carbohydrate fermentation was determined in peptone water with 1% sugar, gelatin liquefaction was tested by Frazier's method and by stab inoculation on 15% gelatin, production of hydrogen sulfide by means of lead acetate test strips, indole by Kovács' reagent, nitrate reduction by Gries-Illosway's reagent, starch hydrolysis by Lugol solution. These methods are quoted in the "Manual of Methods for Pure Culture Study of Bacteria" (1946).

RESULTS

Morphology. The strains of the two species of Sarcina used by us are morphologically identical. They were differentiated from each other only by the size of individual cells that varied from 1.0-2.0μ. All the strains were Gram positive and formed characteristic packets, strains No. 362, 335, 358, 268 only in broth, all the other strains also on nutrient agar.

Cultural characteristics. Colonies both of Sarcina lutea and S. flava were usually round, 0.4-0.6 cm in diameter, raised, granular, profile slightly convex. They were yellow or non-pigmented. Most cultures growing in nutrient broth produced yellow or yellowish sediment. Some cultures deposited a granular sediment on the test tube walls, while broth remained clear. Slight turbidity was formed by strains No. 362, 386, 268. Nearly all the investigated strains produced pigments on nutrient agar, starch agar, blood agar and on potato. An exception occurred with the strains No. 163, 166, and 266, which produced no pigment in the media used.

Biochemical characteristics. The ascertained biochemical characteristics are shown in the table 2.

DISCUSSION

In this study we have endeavored to determine the correctness of present recognition of S. lutea and S. flava as distinct species.

Sarcina lutea Schroeter. Cells spherical, from 1-2μ in diameter. Our findings agree with the original description and with those in Krassilnikov's Guide and in Bergey's Manual (ed. 7). The colony characteristics are essentially identical.

Table 2.

Species	Gelatin Liquefaction		Nitrate Reduction		Indole		Hydrogen Sulfide		Milk		Hemolysis		Glucose		Fructose		Galactose	
	No.		No.		No.		No.		No.		No.		No.		No.		No.	
	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
Sarcina lutea	12	4	1	15	0	16	0	16	3	13	0	16	0	16	0	16	0	16
Sarcina flava	26	2	2	26	0	28	0	28	3	25	0	28	0	28	0	28	0	28

	Lactose		Sucrose		Maltose		Glycerol		Mannitol		Sorbitol		Dulcitol		Sodium Citrate		Acetylmethyl-carbinol	
	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
Sarcina lutea	0	16	0	16	0	16	0	16	0	16	0	16	0	16	0	16	0	16
Sarcina flava	0	28	0	28	0	28	0	28	0	28	0	28	0	28	0	28	0	28

	Methyl Red Test		Starch Hydrolysis		5% NaCl		7.5% NaCl		Urease		Catalase		Lipase	
	+	-	+	-	+	-	+	-	+	-	+	-	+	-
Sarcina lutea	0	16	16	0	16	0	0	16	0	16	16	0	16	0
Sarcina flava	0	28	0	28	28	0	0	28	0	28	28	0	28	0

Comparison on findings relative to cultural characteristics with those of other workers has been somewhat limited by lack of availability of literature. Most strains studied grow and produce some pigment in synthetic media; we have found no accounts of such studies by others. Our data with reference to optimum growth temperature agree with those of other workers.

Data relative to biochemical activity as recorded in the literature show marked differences among strains. Schroeter states that S. lutea usually does not liquefy gelatin, Breed and Smit in Bergey's Manual (1957) record slow liquefaction, Krassilnikov's Guide states no liquefaction. We recorded liquefaction in 12 of 16 strains.

Breed and Smit (Bergey's Manual) state "nitrites generally produced from nitrates"; we found nitrate reduction in one strain of 16. Breed and Smit record production of H_2S, we found all 16 strains negative. These authors also state that litmus milk is coagulated and becomes alkaline. We agree with Krassilnikov that in general milk is not changed (three milk +, 13 -). Krassilnikov states that glucose is fermented, we agree with Breed and Smit that there is no fermentation. It is evident that the Bergey's Manual and Krassilnikov's Guide are not in agreement.

Sarcina flava De Bary. The original description by de Bary states that the cells are 1-2 μ in diameter, as do also Breed and Smit, and we agree. Our results with reference to cultural characters agree with statements of Krassilnikov and of Breed and Smit. De Bary states that S. flava liquefied gelatine. With this conclusion both manuals agree. We found 2 only of 28 strains which were non-gelatin liquefying. Breed and Smit state that this organism does not reduce nitrates, Krassilnikov found that not all strains reduce nitrates, we recorded nitrate reduction in 2 only of 28 strains. All agree that neither indole nor hydrogen sulfide are produced. No coagulation of milk is recorded in the manuals; we found slight peptonization of milk in 3 strains only. We confirm the fermentation of sugars as given by the manuals.

We conclude that the published taxonomic differences, on the basis of which the two species, Sarcina lutea and S. flava were separated were insufficient. In more detailed study of a greater number of strains from both species it was shown that the differences between the two species were

not so outstanding that they can be distinguished by their use. As can be seen in the table 2, investigated biochemical characteristics of both species did not show any differences in the biochemical activity, except in starch hydrolysis. Therefore we assume that this single distinguishing feature, in spite of its importance, is inadequate as a reason for separation of the species. These two species differ neither in gelatin liquefaction as de Bary (1886) and Krassilnikov (1949) indicate, nor in milk coagulation according to Bergey's Manual (1957). Therefore these characteristics cannot be used for species differentiation as these authors suggest. Instead of this we propose differentiation on the basis of starch hydrolysis.

Therefore we suggest the following key for the differentiation of the two species:

I. Aerobic
  A. Not halophilic
    1. Non-motile.
      a. Yellow pigment produced
        (1) Starch is hydrolyzed
          Sarcina lutea
        (2) Starch not hydrolyzed
          Sarcina lutea subsp. flava subsp. nov.

Sarcina lutea Schroeter

Spheres 1-2μ in diameter, in packets of 8. Non-motile. Gram positive. Some strains produce packets only in liquid media.
Agar colonies: (After 2 days) Yellow, circular, usually 3-6 mm in diameter, granular, moist, glistening.
Broth: (After 2 days) Clear, yellow sediment.
Potato: (After 5 days) Slight growth, yellow pigment.
Gelatin liquefaction: Most strains liquefied.
Nitrite not produced from nitrates. Only single strains +.
Indole not produced.
Hydrogen sulfide not produced.
Milk: (After 10 days) Not coagulated, milk slight alkaline or unchanged, only single strains +.
Hemolysis: Negative.
No acid from glucose, fructose, galactose, lactose, sucrose, maltose, glycerol, mannitol, sorbitol, dulcitol.
Sodium citrate: No growth.

Acetylmethylcarbinol: Negative.
Methyl red test: Negative.
Urease: Negative.
Starch hydrolysis: Positive.

Sarcina lutea subsp. flava subsp. nov.
Differs from S. lutea in that it does not hydrolyze starch.

SUMMARY

We have studied 16 strains of Sarcina lutea and 28 strains of Sarcina flava.

We have found that the two species are distinguished only by starch hydrolysis.

Because of minor differences in morphology and biochemical characteristics, we reduce the species Sarcina flava to rank of a subspecies, with the name Sarcina lutea subsp. flava.

REFERENCES

Aaronson, S. 1956. A biochemical-taxonomic study of a marine micrococcus Gaffkya homari and a terrestrial counterpart. J. Gen. Microbiol. 15:478-484.

Arnaki, M. and Z. Stary. 1952. Étude sur la biosynthese des carotenoides chez la Sarcina lutea. Folia Pharmaceutica II(7):3-6.

Bellini, C.C. 1951. A preliminary investigation of mutation production in Sarcina lutea Schroeter. Jour. of Heredity 42:278-284.

De Bary, A. 1887. Vorlesungen über Bakterien.

Besborodov, A.M. 1956. Osobĕnosti sintĕza karotinoidov u želtych sarcin. Mikrobiologyia 24:25-29.

Breed, R.S., E.G. Murray and A.P. Hitchens. Bergey's Manual of Determinative Bacteriology. Baltimore. 1948.

_____, _____ and N.R. Smith. Bergey's Manual of Determinative Bacteriology. Baltimore. 1957. Ed. 6 and 7.

Krassilnikov, N.A. 1949. Oprĕdelitĕl baktĕrij i aktinomycetov. Moskva.

Lehmann, K.B. and R.O. Neumann. 1927. Bakteriologische Diagnostik. München.

Manual of Methods for Pure Culture Study of Bacteria. 1946. Geneva, New York.

Miller, M.A. 1954. Observations of morphological and pigment variation in Sarcina lutea. Turtox News 32:11.

Pijper, A. 1955. The Sarcinae. Kind of flagella and specific agglutination. Jour. Bact. 69:151-158.

Shaw, C., J.M. Stitt and S.T. Cowan. 1951. Staphylococci and their classification. Jour. Gen. Microbiol. 5:1010-1023.

Schroeter, J.R. 1886. Kryptogamenflora von Schlesien. III (1):154.

Winslow, C.E.A. and A.R. Winslow. 1908. The systematic relationship of the Coccaceae. New York.

Witkus, R. 1948. A predictable mutation in bacteria. Proc. Nat. Acad. Sci., Washington. 34:442.

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NONCONFORMISM IN NOMENCLATURE

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Kauffmann (1959. Internat. Bull. 9:1) has made proposals that, if acted upon, would throw science into confusion. His main proposal is that the serotype of any organism in the Enterobacteriaceae should be regarded as a species, thus creating hundreds of new and unnamed species. It is obvious that Kauffmann has not thought out the consequences of so many unnamed species. Either new names would have to be found for over one hundred Escherichia coli serotypes, or the rules of nomenclature would be abandoned and the new "species" referred to by number. As the second course would be unacceptable to the Nomenclature Committee, a multitude of new epithets is the only possible consequence. Kauffmann extends his proposals to all serotypes, so even he must boggle at the idea of finding new epithets for all the serotypes of Arizona, Klebsiella, Hafnia, Proteus, Providence, Citrobacter, and Cloaca.

The problem of species definition in bacteriology is almost insoluble and Kauffmann's proposal is extreme. It would be rather more logical to go to the other extreme of regarding each group of the Enterobacteriaceae (Salmonella, Arizona, Cloaca, etc.) as a species, and the further subdivisions as subspecies or serotypes. This would be much more in accordance with the thoughts of most workers, and would make it easier to explain the great overlapping of cultural and serological characters within the family. However, this other extreme would be equally unacceptable because it would mean too many changes of nomenclature.

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ON THE PAST AND PRESENT NOMENCLATURE OF CERTAIN BACTERIA

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The following essay is a plea for the consideration of giving descriptive names to any newly recorded bacteria in preference to the modern practice of using names of people, places or even any word. All three are permissible under the present rules of nomenclature.

In the early days of microbiology most of the names given to those "animalcules" we now call bacteria had a definite meaning and were in fact a brief description of the micro-organisms concerned. They were moreover derived from Latin or Greek words.

Rule 5 of the International Bacteriological Code of Nomenclature (5) permits the creation from any source whatever of both generic and species (trivial) names for bacteria, no matter if the name or word proposed means anything or is a mere sound. Usually such names are manufactured from those of persons or places and are in no sense descriptive. Unlike the older names, many modern ones convey no information at all about the nature of the bacterium concerned.

For those unacquainted with Latin or Greek, reference to a classical dictionary will explain the meaning of the words derived from the ancient languages and will tell them at once something about the organism. This is not so with the words derived from the names of persons or places. No dictionary defines Escherichia or Klebsiella and a student may well wonder what sort of an organism Klebsiella is. To be informed that this mysterious sound is the name of a genus of bacteria and was given by Trevisan in honour of the late Professor Klebs only adds to the enquirer's bewilderment. It does not tell him what he really wants to know which is something about the organism, i.e. is it rod-shaped, spherical or spiral or has it any prominent character such as gas-formation?

The following examples are cited to emphasize the above remarks. Some of the original names are still in use and are valid. Thus, in 1773 Muller named a motile, comma-

shaped microbe Vibrio which is derived from the Latin vibro, I vibrate or tremble. The name of the cholera pathogen given by Bergey (2) is V. comma (Schroeter) Winslow et al., a descriptive name signifying the vibrating comma-shaped organism. Similarly Ehrenberg in 1830 coined the name Spirillum from the Greek speira, a coil, and S. undula (Muller) Ehrenberg describes two characteristics of one species and means the wave-like coiled microbe. In 1872 Cohn called the common hay organism Bacillus subtilis which is derived from the Latin bacillum, a little rod, and subtilis, slender. The name is again descriptive and means the slender little rod. Escherich in 1885 named the common bacterium of the colon Bacterium coli commune partly from the Greek bakterion, a little rod, and partly from Latin. The meaning of the name is quite obvious—the little rod common in the colon. In 1897 Chester called a frequently occurring, gas-forming micro-organism Bacterium aerogenes from the Greek aer, air or gas, and genao, I generate. The name describes two characters of the organism and means the gas-generating little rod.

An older name which however was not descriptive was that of the micro-organism responsible for the apparently miraculous blood-red colouring of carbohydrate-containing substances such as maize meal. It was named Serratia marcescens in 1823 by Bizio in honour of the Italian physicist Serrati. The trivial name is Latin, marcescens, meaning withering away or dissolving, so that the name Serratia marcescens signifies the withering away or dissolving Serrati. Many other generic names have been used for this organism and a further trivial name, prodigiosa, was given by Ehrenberg in 1849, meaning miraculous. Topley and Wilson (7) used the very sensible and descriptive combination Chromobacterium prodigiosum (from the Greek chroma, colour,) i.e. the miraculous coloured small rod. Bergey (2) reverts to the original one given by Bizio, on grounds of priority, because the starting date for bacteriological nomenclature is considered to be Linnaeus, Species Plantarum, Ed. 1, 1 May 1753. However, as Ainsworth and Cowan (1) state, "many bacteriologists think that the starting date should be much later, and certainly in the era of pure cultures".

In recent years the older names have been superseded by words derived from the names of eminent deceased men

of science, not always bacteriologists. Thus in 1919 Castellani and Chalmers proposed the name Escherichia coli in honour of Escherich who first described and named the colon bacterium Bacterium coli commune. Escherichia coli means the Escherichia of the colon. But what is an Escherichia and how is it pronounced?

Beijerinck in 1900 proposed the name Aerobacter aerogenes, almost a tautonym, for the former Bacterium aerogenes; but this is surpassed by the most recent proposal, again on the grounds of priority, to call this organism Klebsiella aerogenes (the genus Klebsiella was created by Trevisan in 1885 in honour of Klebs) and the name means literally the gas-generating little Klebs!

Apart from these inappropriate names Ainsworth and Cowan (1) admit a taxonomic difficulty in that Klebsiella and Aerobacter can seldom be separated so that "B" aerogenes may have two generic names according to the interpretation of all its characters as determined by each investigator.

In view of the above considerations the author suggests that the establishment of an appropriate new generic name may not only solve some of these nomenclatural and taxonomic problems but will also provide a substitute for the generic name Bacterium, in which the author (3) placed the coliform bacterial plant pathogens and some other similar bacteria. Bacterium is now invalid, International Bulletin of Bacteriological Nomenclature and Taxonomy, (6) and at present these coliform plant pathogens may be considered as either species of the genus Erwinia Winslow et al. (9) or Pectobacterium Waldee (8). The first is not descriptive as it is derived from a person's Christian name but the second can be applied to those coliforms possessing pectic enzymes, such as the soft rot bacteria of the plant pathogens, and for these it is a very suitable generic name (Dowson, 4).

The possible objection that there is not enough variety in bacterial morphology or physiology from which to coin descriptive names of all bacteria may be met by the undoubted fact that there are far too many genera based on only one or two characters which could be combined. The various species would be distinguished by trivial names e.g. the specific epithets fluorescens and berberidis distinguish two species of the genus Pseudomonas and the one generic name

conveys the further information that both species possess some characters in common. (fluorescens = producing fluorescence and berberidis = of the barberry; Pseudomonas, Greek pseudes false and Monas a genus of infusoria = the false Monas).

It is perhaps significant that the specific epithets of bacteria do not in general change and in the laboratory a bacterium is recognized by its species name without reference to its genus the name of which may be subject to change. The name "coli", for instance, is usually understood to refer to one group of very similar organisms no matter whether the generic name has been changed from Bacterium to Escherichia. Similarly the name "aerogenes" alone is generally sufficient to identify the bacterium whose generic name has been subjected to more than one alteration, i.e. from Bacterium to Aerobacter and now to Klebsiella.

REFERENCES

1. Ainsworth, G.C. and S.T. Cowan. (1954). J. Gen. Microbiol. 10:465.
2. Bergey, D.H. et al. (1948). Manual of Determinative Bacteriology. Williams and Wilkins Co., Baltimore.
3. Dowson, W.J. (1949). Manual of Bacterial Plant Diseases. A. and C. Black, Lond.
4. _____. (1957). Diseases of Plants due to Bacteria. Camb. Univ. Press.
5. International Bacteriological Code of Nomenclature. (1947) in J. Bact. 1948. 55:287 and J. Gen. Microbiol. 1949, 3:444.
6. International Bulletin of Bacteriological Nomenclature and Taxonomy. (1953). 3(4):159.
7. Topley, W.C. and G.S. Wilson. (1931). Principles of Bacteriology and Immunity. Arnold, London. 1st ed. p. 402.
8. Waldee, E.L. (1945). Iowa State Coll. J. Sci. 19:435.
9. Winslow, C.E.A. et al. (1917). J. Bact. 2:560.

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SOME PROBLEMS IN THE IDENTIFICATION AND CLASSIFICATION OF SPECIES OF SPIRILLUM
II. LATER TAXONOMY OF THE GENUS SPIRILLUM

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Giesberger's Taxonomy

Giesberger (1936) was the first investigator of the genus Spirillum to define certain physiological characters useful in identification. He accomplished this by determining, in a mineral base medium, the utilization of various carbon compounds as the sole source of carbon and energy. Giesberger found in his strains good correlation between utilization patterns and distinctive morphology; each distinctive morphological group utilized a distinctive group of carbon compounds. This coupling of the distinctive morphology with the utilization of selected carbon compounds makes possible the identification of his species. However, the pattern of the utilization of the carbon compounds does not in all cases correlate with morphology. Williams and Rittenberg (1957) found that four morphologically distinct groups of strains of Spirillum utilized the same carbon compounds. In such cases with a choice between physiological and morphological criteria in distinguishing species, morphological characters were chosen as being the more distinctive. Giesberger (1936), himself, separated and tentatively identified his species on the basis of morphological criteria; the utilization of the carbon compounds was an additional but secondary character in the diagnosis.

Giesberger (1936) provided exact morphological descriptions (including measurements) as well as growth characteristics for the five species studied by him. The photographs of his species are reproduced as Figs. 7, 8, 9, and 10. His table, showing the utilization of the carbon compounds by the various morphological types, is reproduced as Table 1. Giesberger made a systematic survey of the species of Spirillum, described in the literature up to 1936, rejecting all inadequately described species with two exceptions. Giesberger (1936) considered the morphology of

Table 1. Utilization of Various Compounds as Sole Carbon Source (Reproduced from Giesberger's (1936) dissertation: Beitrage zur Kenntnis der Gattung Spirillum Ehbg.)

	Cultures of morphological Group I (S. serpens)	Cultures of morphological Group II (S. itersonii)	Cultures of morphological Group III (S. tenue)	Cultures morphologi Group IV (S. undu
SATURATED FATTY ACIDS				
Formic acid	-	-	-	-
Acetic acid	+	+	+	(+)
Propionic acid	-	(+)	(+)	-
n-butyric acid	+	+	+	-
OTHER ACIDS				
Oxalic acid	-	-	-	-
Succinic acid	+	+	+	+
Fumaric acid		+		
Malonic acid		-		
D-lactic acid	+	+	+	(+)
Citric acid	-	+	+	-
DL-malic acid	+	+	+	(+)
D-tartaric acid	-	-	-	-
Pyroracemic acid (Pyruvic)	+	+	+	+
CARBOHYDRATES				
Xylose	-	(+)	(+)	-
Arabinose	-	(+)	(+)	-
Glucose	-	+	+	-
Levulose	-	+	+	-
Mannose	-	(+)	(+)	-
Galactose	-	(+)	(+)	-
Maltose	-	(+)	(+)	-
Lactose	-	(+)	(+)	-
Saccharose	-	(+)	(+)	-
ALCOHOLS				
Methyl alcohol	-	-	-	-
Ethyl alcohol	-	+	-	(+)
n-propyl alcohol	-	+	-	(+)
n-butyl alcohol	-	+	-	(+)
Glycerine	-	+	(+)	-
Mannitol	-	-	-	-
Ethylene glycol	-	-	-	-

\+ = Growth
(+) = Weak growth
\- = Absence of growth

S. volutans and S. minus to be so distinctive that these organisms could be recognized on this basis alone. Giesberger suggested the transfer of some species to other genera, a recommendation which has been accepted for a number of these organisms by Bergey's Manual (7th ed., 1957). The details of Giesberger's reclassification of the species of Spirillum has been discussed elsewhere. (Williams and Rittenberg, 1957).

Giesberger (1936) was able to obtain very few cultures of species of Spirillum from other workers and laboratories. Two strains of S. tenue, isolated by den Dooren de Jong (1926), were obtained from the Laboratory of Microbiology in Delft and a culture of S. virginianum (Dimitroff, 1926) from the American Type Culture Collection. The physiological characters of these cultures, as originally described by de Jong and by Dimitroff, showed some changes and did not agree in all respects with those found by Giesberger (1936). That such changes occur in cultures of the bacteria maintained for long periods of time has been recognized by all who work with them. To prevent such changes from occurring in bacteria, it is customary to lyophilize stock cultures of many groups. As yet, it has not been possible to maintain viable lyphilized cultures of species of Spirillum by the customary methods. Dr. W.C. Haynes, ARS Culture Collection Investigation (Northern Regional Research Laboratories, U.S. Department of Agriculture, Peoria, Illinois) has been able to maintain lyophilized cultures of species of Spirillum by using bovine serum and reducing the period of desiccation (personal communication). Such lyophilized cultures (maintained for periods of time ranging from 2 to 15 years) are viable, and, in some instances, typical morphology has been maintained. In cultures maintained by routine transfer, "dissociation" is a common occurrence (Williams and Rittenberg, 1957). In view of the fact that such changes may and do occur in species of Spirillum, maintained as stock cultures, it is recommended that descriptions (where these have been adequately presented) be used in the identification of isolates of this genus until such time as reliable type or neotype cultures may be maintained.

Giesberger (1936), noting that differences occurred in the morphology of cells of a pure culture of species of Spirillum, discussed this problem as follows:

> Before a bacteriologist starts on the description of the form of a given bacterium, he must realize that the bacterial cell is not to be considered as a static but rather as a more or less dynamic complex. As external conditions change, this complex may react with a change in cell form. . . .
>
> Variation in cell form, occurring in an otherwise uniform culture, is likewise a point to which attention should be given, since, in the spirilla, especially, the spiral shape may be more pronounced in one cell than in another. One often finds rod-shaped and yet highly motile cells. In general, however, 80 to 90 per cent of the cells of the cultures isolated from water were completely uniform, so that a reliable basis for the description of cell form exists.

In order that such a reliable basis for the description of cell form might be established for species of Spirillum, Giesberger (1936) recommended that all measurements and descriptions of cell form be made under standard conditions. He used 24-hour cultures grown in peptone water at 30°C for this purpose.

Variation in cell form in species of Spirillum, while noted by Giesberger, were not described explicitly. Variation due to external conditions or to changes in the composition of the medium has been shown by van Niel (1944) in Rhodospirillum rubrum. Williams and Rittenberg (1957) noted minor differences in cell form of isolates of the same general morphological type even under standard conditions of the composition of the medium and cultures. In some instances, these differences were so slight that they could be considered to be the normal variation; in other cases, the differences were of such magnitude that the possibility that a subspecies or even a different species was involved had to be considered.

Forms intermediate between two distinct morphological types are not new and have plagued taxonomists in all fields. Bacteriologists, however, do not have the numerous so-called "nonessential" characters of higher forms nor ecological and sexual differences for use in deciding the status of such intermediate forms. The investigator, confronted

with the problem of correct taxonomic position of such intermediates could well echo Cohn's complaint (quoted earlier) about the difficulties involved in speciation in bacteria. As a rule, the decision as to the taxonomic position of such intermediate forms depends on the individual judgment of the taxonomist, the decision is a subjective one. The International Code of Nomenclature of the Bacteria and Viruses (1958) affords some assistance, particularly through recognition of subspecies and of infrasubspecific forms.

Variations in cell form within a species of Spirillum may be illustrated from one species. Among the many strains of the genus Spirillum isolated in the author's laboratory were many agreeing in morphology with Giesberger's S. serpens. Approximately 60 such cultures were obtained from natural sources; of these 18 were retained for further study on the basis of slight differences in morphology. When these isolates were tested by the use of several carbon compounds, it was found that the differences in morphology were also reflected in metabolic differences. None of the isolates agreed, in all details, with the description of S. serpens, as given by Giesberger (1936) which reads as follows:

"Spirillum serpens Giesberger

> In peptone water highly motile, cells turns rather shallow; width of cells 0.8 to 1.0 μ; length of turn 8.0 to 9.0 μ; width of turn 1.5 to 1.8 μ.
>
> Motile by means of bipolar flagella tufts. Volutin occurs as reserve material. Gram-negative. Catalase positive. Non-spore-forming. Rich growth on peptone agar. Colonies cream colored, typically folded. Liquefies gelatin slowly. Light orange-yellow growth on potato. Only acetic, n-butyric, succinic, lactic, malic, and pyroracemic (pyruvic) acids are suitable growth substrates. In addition to complex organic compounds, NH_4 compounds are utilized as nitrogen sources."

The dimensions of our laboratory isolates, while coming within the range cited by Giesberger for S. serpens, did

not agree exactly. None of the isolates liquefied gelatin and all of them utilized nitrate and urea as nitrogen sources, a characteristic not found by Giesberger for any of his isolates. A few of the organisms showed a transient growth on sugars and alcohols; some would not grow on unsupplemented peptone media; others showed a very restricted pattern in the utilization of the carbon compounds. The problem of which isolates were to be regarded as true representatives of the species S. serpens was resolved by selection of the strain which most nearly agreed in its characters with those given by Giesberger (1936) for S. serpens, designating this as a variety, and regarding the remaining cultures as infrasubspecific variants or forms. This procedure, however, did not provide a permanent solution to the problem of these apparently aberrant forms of S. serpens. Later other spiral organisms, morphologically similar to S. serpens, were isolated from widely varied geographical sources; none of the strains exactly fit Giesberger's description of S. serpens. Further, none of them are the same as the S. serpens var. azotum Williams and Rittenberg (1957).

The only other spiral organism, similar to S. serpens morphologically, is Vibrio rugula (Fig. 3, no. 16) described by Cohn (1872). Cohn distinguished V. rugula from V. serpens on the basis of fine cytoplasmic inclusions in V. rugula. He noted also differences in the character and number of spiral curves, differences in cell diameter, and the fact that in cells of V. rugula a distinct swelling may occur in the center. Migula's (1900) description of Spirillum rugula is essentially the same as that of Cohn's V. rugula in regard to the morphological characters except that he did not refer to a central swelling. The growth characteristics, given by Migula for S. rugula, are not sufficiently different from those given for S. serpens, to distinguish the two species. At the present time, S. rugula has been assigned to an appendix of the genus Spirillum Ehrenberg as being inadequately described. It is highly probable that this center swelling, described and illustrated for V. rugula by Cohn (1872), is the source of the mention of spore-formation in species of Spirillum by Migula (1900) and others. The swelling in the cells of V. rugula, as described and illustrated by Cohn is similar to microcyst formation by protuberances, described by Williams and Rittenberg (1956). Since no cultures of Vibrio rugula (Spirillum rugula) are

known to exist, it is not possible to determine if this species forms microcysts. Even if microcyst formation may occur in S. rugula, none of the morphological forms, grouped together as S. serpens, produce microcysts.

These aberrant forms (infrasubspecific forms, variant strains) were considered to be variants of Giesberger's S. serpens and his description was taken as a basis for fixing a "neotype" for this morphological type. Variations in the morphology of either Vibrio serpens or Spirillum serpens, as depicted by the various bacterial taxonomists discussed earlier, are shown in Fig. 11. With the exception of Müller's drawing, the morphology of all the organisms shown is similar. Organisms similar to the symmetrically curved organisms shown by Müller (1786) may be obtained by mixing certain of the variant strains in pairs in liquid media, allowing the organisms to fuse, and isolating them in symmetrical form. The only character mentioned by all individuals (Müller, 1786; Cohn, 1872; Migula, 1900; and Giesberger, 1936) for either V. or S. serpens is the apparent straightening of the cells during rapid motion. All the varient strains show this character which has been illustrated by Pijper et al. (1953) in cinematographic records of motility in this organism.

The answer to the problem of the variant strains of S. serpens is not solved by the creation of a large number of subspecies, differing only in minor details. A solution is provided, however, by Rule 8, Recommendation 8a of the International Code of Nomenclature of the Bacteria and Viruses (1958).

> (2) Type is a term which has frequently been used to designate a subdivision of a species, particularly in cases where the distinguishing characters are regarded as insufficient to justify the erection of a subspecies. Types are often distinguished on the basis of antigenic characters. However, in view of the use of the word "type" in a different sense as defined in Principle 11 and Rule 9, it is recommended that the terms serotype (or serological type), biotype (or physiological type), phagotype (or phage type), and morphotype (or morphological type) be appropriately substituted for type as a designation of a subdivision of a species.

This recommendation proposes a method of naming or designating strains within a species showing differences in morphological characters. The significant term is "morphotype" which is defined as "a subdivision of a species distinguished by possession of some special or unusual morphological character." Note must be taken of the provision that for every species there should, wherever possible, be recognized a "nomenclatural type" as defined in Principle 11 and applied in Rule 9. Principle 11 states "A nomenclatural type is that constituent element of a taxon with which the name of the taxon is permanently associated." None of the earlier cultures of Spirillum serpens are known, hence no authentic type culture is available. Giesberger, however, reisolated an organism which he considered to be identical with his original isolate of this organism. This organism has been deposited with the American Type Culture Collection by Williams and Rittenberg (1957) and designated as the neotype culture for this species (ATCC No. 11130).

The variations in the morphology of S. serpens and its variant strains are shown in Fig. 12. Giesberger's S. serpens var. serpens, the variety S. serpens var. azotum (Williams and Rittenberg, 1957), and four morphotypes are shown. Such variation in both morphological and physiological characters are found in other species of Spirillum. A more detailed account will be presented elsewhere.

It is highly doubtful that the species, S. serpens, S. undula and S. tenue, as described by Giesberger (1936), are identical to the organism called by these names by earlier authors. Nevertheless these organisms are sufficiently well described and figured by Giesberger (1936) so that they can be reidentified with some confidence. The descriptions of these species by earlier authors, are inadequate, and about all that can be said in regard to an isolate is that it is "morphologically" similar to a particular drawing or photograph by Ehrenberg (1838), Cohn (1872) or Migula (1900). Some other problems connected with the taxonomy of Spirillum will be mentioned briefly. One such problem is that of the identification of the type species of the genus.

The only species described and named in Ehrenberg's (1830) first description of the genus Spirillum and S. volutans, which became the type species (selection by monotypy),

This designation of the type species was first indicated by Stiles (1905). This designation of Spirillum undula as type species by Vuillemin (1913) is incorrect because S. undula was not included at this time (1830). In 1838 Ehrenberg named a new species, S. tenue. He (1832) transferred to the genus Müller's V. undula as Spirillum undula and S. undula is incorrectly designated as the type species in Bergey's Manual, 1957.

Diagnoses of these species, however, have not remained uniform through the years. It is doubtful that the Vibrio undula of Müller (1773, 1786) is the same as the Spirillum undula of Ehrenberg (1838) or even of Cohn (1872). The description of S. undula as given by Giesberger (1936) is not the same as that by Migula (1900); as shown by a comparison of the photographs of S. undula by the two authors (Figs. 5 and 9). Nor is it the same (Fig. 9) as shown in the drawing of S. undula by Cohn (Fig. 3, no. 20). It is even doubtful that any two investigators of the genus Spirillum have given the name S. undula to identical organisms. Two subspecies of Spirillum undula were described by Kutscher (1895) and called S. undula majus and S. undula minus; the two organisms differed in size, type of spiral curves and origin. Giesberger (1936) believed his species to be the same as that described by Cohn (1872) and similar to Kutscher's S. undula minus.

Some difficulties arise as a result of the necessary acceptance of S. volutans as the type species due to the fact that it has never been obtained in pure culture, at least there is no such culture known, This objection has recently been removed by the isolation of this organism in pure culture, by Dr. S.C. Rittenberg (unpublished experiments) even though the satisfactory cultivation of the organism still presents some problems. There is little doubt that a suitable medium for the growth of S. volutans in pure culture will be found in the near future and all objections to this organism as the type species will be removed, making possible the recognition of a neotype culture. The history of the genus Spirillum Ehrenberg indicates that once a particular spiral organism has been shown to have a distinctive type of physiology, it is promptly removed to another genus, leaving only those spiral organisms whose chief physiological characteristics appear to be growth, provided the correct medium can be devised. The difficulties in the isolation

and cultivation of S. volutans indicated that this organism will have some distinctive physiological characters. In the event that the genus Spirillum is divided in the future, then the name of the genus, Spirillum Ehrenberg, would remain with Spirillus volutans.

The descriptions and number of species in the genus Spirillum Ehrenberg have not been changed from the 6th to the 7th editions of Bergey's Manual (1957). The diagnosis of the genus also remains the same. Recently Williams and Rittenberg (1957) have proposed a new diagnosis of the genus Spirillum to accommodate new species, isolated by them and described as having only a single flagellum. The key to the species of the genus contains all adequately described species with one exception, Spirillum lipoferum, described by Beijerinck (1926). This organism was omitted due to the recommendations of Giesberger (1936) who, following the procedures given by Beijerinck, isolated an organism which he (Giesberger) considered similar to S. lipoferum. Due to the fact that the organism which he isolated was only slightly curved and had only a single flagellum, Giesberger (1936) recommended that the organisms be placed in the genus Vibrio. Since Williams and Rittenberg (1957) emended the diagnosis of the genus Spirillum Ehrenberg to accommodate species showing only a single flagellum, the omission of S. lipoferum on this basis is unjustified and it should be included. The change in the diagnosis of the genus Spirillum to accommodate species showing only a single flagellum brings up a new problem; that of differentiating between species of the two genera, Vibrio and Spirillum.

The distinction made by Migula (1895, 1900) between the two genera on the basis of flagellation (one to three polar flagella for the genus Vibrio and tufts of flagella for the genus Spirillum) provided a definite criterion for the separation of the species of the two genera. The elimination of this criterion by Williams and Rittenberg (1957) makes it difficult to establish generic limits. The tendency of species of Spirillum to lose their typical spiral curvature, thus appearing as straight rod-like organisms, also contributes to the difficulty of distinguishing the genera Pseudomonas, Vibrio, and Spirillum. By substituting the genus Pseudomonas for the genus Bacterium, the complaint of Cohn (1872), quoted earlier, could be echoed for the difficulties in allocating the several species in the three genera. To

paraphrase Cohn, there are definite rod-like, Gram-negative organisms, with a single polar flagellum which display fluorescence and have a number of physiological characteristics, which may be placed without hesitation in the genus Pseudomonas; there are other short, slightly curved or bean-shaped organisms, having only a short single polar flagellum, which may be placed in the genus Vibrio; there are also corkscrew-spiralled organisms with a tuft of polar flagella which can easily be placed in the genus Spirillum. Between the two limits of rod-shaped organisms with a long curved polar flagellum (the genus Pseudomonas) and corkscrew-spiralled organisms with tufts of polar flagella (the genus Spirillum) there are many intermediates. If only those organisms, characterized mainly by a lack of definite physiological characters were included, the similarity between these intermediate forms would be emphasized. In a recent article on Bacterial Classification, Sneath (1957), makes the following comment on the problem of intermediate forms:

> "In higher organisms we also find intermediate forms, but this does not shake our faith in classification (that is to say degress of similarity). It is simply an expression of the fact that relationship is an infinite variable quantity. . . . There are 'points of rarity' in distributions of features where individuals with certain combinations of features are rare. . . If there is no point of rarity, it is useless to make a division, since we say 'these cannot be separated'."

Sneath (1957) is also critical of "intuition" as a guide in the separation of species and genera of bacteria. Recently Shewan and Hodgkiss (1954) have proposed the use of certain "vibriostatic" agents as a means of differentiating species of Vibrio from those of Pseudomonas. It is possible that similar agents may be found which will differentiate species of Vibrio from those of Spirillum.

The difficulties of determining the type of flagellation in species of Spirillum by means of flagellar stain preparations has been discussed by Williams and Rittenberg (1957). If unfixed cells are used, many of the species show only a

single flagellum; if any type of fixation is used (including formalin and heat) tufts of flagella are often observed in the flagellar preparations on species which show only a single flagellum in preparations using unfixed cells. Even in flagellar stain preparations using fixed cells, organisms could be observed (in the same slide) which showed a single flagellum at both poles; one flagellum at one pole and two or more at the other pole; or cells with tufts of flagella. Flagella stains are either inadequate for determining the true state of flagellation in species of Spirillum or more than one type of flagellation may exist in cells of the same species. Electron microscope studies of flagellation have not been used for species of bacteria for purposes of taxonomy; most of such work has been done on the flagella of the bacteria in connection with the controversy over the function of flagella—whether they are the cause or the result of motility in bacteria. Some of the work done with the electron microscope on species of the Spirochaetales may have taxonomic significance but was not carried out primarily for this purpose. On the other hand, flagellar stains have been used for taxonomic purposes; i.e., as used by Leifson on speciation in Chromobacterium.

Electron micrographs of spiral organisms by various individuals indicate that real differences may exist in the type of flagellation to be found. Three main types have been shown in the flagella of these organisms: (1) true tufts of flagella, which appear to originate from the entire end of the cell, as shown by van Iterson (1947) and Houwink (1953) (2) small tufts arising from a circumscribed area at the end of the cell, as shown in photographs by van Iterson (1953) and Grace (1954); (3) a single flagellum in species of Vibrio in photographs by van Iterson (1953) and Grace (1954). A single flagellum has been shown by Pease (1956) for small cells of Spirillum undula, which she (Pease) has called "gonidia". These "gonidia" develop into larger spiral cells showing tufts of flagella. Until more data are obtained on the type of flagellation in species of both Vibrio and Spirillum, this particular character will have little significance in the taxonomy of these organisms.

The format and arrangement of the genera and species in the 7th edition of Bergey's Manual has undergone considerable change from that found in the 6th edition. The principal change has been an increase in the number of or-

ders and the arrangement of the genera and species in these orders. The Gram-negative, polar flagellated organisms have all been placed in the order Pseudomonadales, which contains two suborders and eight families. Five of these families contain spiral organisms but the majority of the species are found in the family Spirillaceae, which has ten genera. A perusal of the keys to the genera made by Skerman (1957) [to be found in the back of Bergey's Manual (1947)] will show four other orders as well as an addendum to the Class Schizomycetes von Naegeli which contain spiral organisms. The majority of these spiral organisms occur in sheaths or in trichomes and are thus well differentiated from the free-living spiral cells found in the order Pseudomonadales. Any relationship between spiral cells which occur in trichomes or sheaths and the free-living spiral cells must await comparative studies of both types of organisms. It is entirely possible that the spiral shape is simply fortuitous.

SUMMARY

The following recommendations are made in regard to the identification and classification of species of the genus Spirillum Ehrenberg.

1. The diagnoses of the five species of Spirillum—S. serpens, S. undula, S. tenue, S. itersonii and S. kutscheri—should be emended to conform to those given by Giesberger (1936).

2. Neotype cultures of adequately described species of the genus Spirillum should be used as aids in the identification of isolates. In the event that the characteristics of the strain isolated do not agree, in all details, with those of the neotype, it may be designated and named as a morphotype with the distinguishing characters listed.

3. The distinctive and unique morphologies of the species of Spirillum should be the primary basis for species separation with physiological characters used where needed in the identification of the species of adequately described organisms.

4. The type species of the genus Spirillum Ehrenberg is Spirillum volutans Ehrenberg 1830, not S. undula Ehrenberg 1830.

The need for further investigations in connection with

all characters of species of Spirillum has been emphasized. Until more data are obtained, the differentiation between the various spiral bacteria, as found in Bergey's Manual (1957, 7th ed.) will serve, provided it is realized that much of this differentiation is based on incomplete and inadequate knowledge.

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REFERENCES

1. Beijerinck, M.W. 1893. Atmungfiguren beweglicher Bakterien. Zentral. Bakt. Parsitenk. Abt. I, Orig. 14:827-845.
2. _____. 1925. Uber ein Spirillum welches freien stickstoff binden kann? Zentral. Bakt. Parasitenk. Abt. II. 63:353-359.
3. Breed, R.S., E.G.D. Murray, and N.R. Smith. 1957. Editors: Bergey's Manual of Determinative Bacteriology, 7th. ed. The Williams and Wilkins Company, Baltimore.
4. Buchanan, R.E. 1918. Studies in the nomenclature and classification of the bacteria. VI. Subdivisions of genera of the Spirillaceae and Nitrobacteriaceae Jour. Bact. 3:175-181.
5. Cohn, F. 1872. Untersuchungen uber Bakterien. I. Beitrage zur Biologie der Pflanzen I. (Helt 1). Breslau.
6. _____. 1875. Untersuchungen uber Bakterien II. Beitrage zur Biologie der Pflanzen I. (Heft 3). Breslau.
7. Cowan, S.T. 1955. The principles of microbial classification. Jour. Gen. Microbiol. 12:314-321.
8. _____. 1956a. "Ordnung in das Chaos" Migula. Can. Jour. Gen. Microbiol. 2:212-219.

9. _____. 1956b. Taxonomic rank of enterobacteriaceae "Groups". Jour. Gen. Microbiol. 15:345-358.
10. den Dooren de Jong, L.E. 1926. "Bijdrage tot de Kennis van het Mineralisatie-proces" Thesis, Rotterdam, as quoted by G. Giesberger, 1936.
11. Dimitroff, V.T. 1926. Spirillum virginianum nov. spec. Jour. Bact. 12:19-38.
12. Dujardin, F. 1841. Histoire Naturelle des Zoophytes infusoires. Paris.
13. Ehrenberg, C.G. 1930. Beiträge zur Kenntniss der Organisation der Infusorien und ihrer geographischen Verbreitung. Abhandl. d. Berl. Akád. pp. 1-80.
14. _____. 1932. Beitrage zur Kenntnis der Organization der Infusorien und ihrer geographischen Verbreitung, besonders in Siberien. (Gelessen in der Akad. d. Wiss. am 4 und 18 Marz 1830, mit Zusatzen gedrukt am 13 Aug.) Physik. Abhandl. K. Akad. Wissench. Berlin. p. 38.
15. _____. 1838. Die Infusionthierchen als volkommene Organismen. Leipzig.
16. Giesberger, G. 1936. Beitrage zur Kenntnis der Gattung Spirillum Ehbg. Dissertation, Delft.
17. Grace, J.B. 1954. Some observations on the flagella and blepharoplasts of Spirillum and Vibrio spp. Jour. Gen. Microbiol. 9:325-327.
18. Hermann and O.F. Müller. 1784. Vibrio Undula. Naturforscher. XX p. 150, as quoted by Ehrenberg, 1838.
19. Houwink, A.L. 1953. A macromolecular mono-layer in the cell wall of Spirillum spec. Bioehem. et Biophys. Acta. 10:360-366.
20. Judicial Commission. 1958. International code of nomenclature of the bacteria and viruses.
21. Koch, R. 1877. Untersuchungen uber Bakterien: VI. Verfahren zur Conserviren und Photographiren der Bakterien. Beitrage zur Biologie der Pflanzen, 2 (Heft 2).
22. Kohler. 1777. Schraubenformigs Thierchen. Naturforscher X. p. 103 as cited by Ehrenberg, 1838.
23. Kutscher, H. 1895. Spirillum undula minus und Spirillum undula majus. Zentral. Bakt. Parsitenk. 18: 614-616.

24. Leeuwenhoek, A. Letters: Epistulae physiol. and Arcene Naturae 96 as cited by O.F. Müller, 1786.
25. Leifson, E. 1956. Morphological and physiological characteristics of the genus Chromobacterium. Jour. Bact. 71:393-400.
26. Migula, W. 1895. Schizomycetes in A. Engler and K. Prantl's Die naturlichen Pflanzenfamilien, Teil 1, Abteilung a, 1-44.
27. _____. 1897 and 1900. System der Bakterien. Volumes I and II. Gustav Fischer, Jena.
28. Müller, O.F. 1773. Vermium terrestrium et fluviatilium.
29. _____. 1786. Animacula infusoria fluviatilia et marina, Hauniae.
30. Pease, P. 1956. The gonidial stages in Spirillum, spp. and Vibrio spp. Jour. Gen. Microbiol. 14:672-675.
31. Pijper, A., C.G. Crocker, J.P. van der Walt, and N. Savage. 1953. Flagellum and motility of Spirillum serpens. Jour. Bact. 65:628-635.
32. Schröter, G. 1886. Die Pilze in Cohn's Kryptogamen Flora von Schlesien.
33. Shewan, J.M. and W. Hodgkiss. 1954. A method for the rapid differentiation of certain non-pathogenic asporogeneous bacilli. Nature 173:208-211.
34. Skerman, V.B.D. 1957. A key for the determination of the generic position of organisms listed in the Manual. in: Bergey's Mauual of Determinative Bacteriology, 7th ed.
35. Sneath, P.H.A. 1957. Some thoughts on bacterial classification. Jour. Gen. Microbiol. 17:184-200.
36. Stiles, C.W. 1905. The International Code of Zoological Nomenclature as applied to Medicine. Bull. Hygienic Laboratory 29. Washington, D.C.
37. van Iterson, W. 1947. Some electron-microscopical observations on bacterial cytology. Biochem. et Biophys. Acta 1:527-548.
38. _____. 1953. Some remarks on the present state of our knowledge of bacterial flagellation. Symposium: Bacterial cytology. Charles C. Thomas, Springfield, Illinois.

39. van Niel, C.B. 1944. The cultures, general physiology, morphology, and classification of the non-sulfur purple and brown bacteria. Bact. Rev. 8:1-118.
40. Vuillemin, Paul. 1913. Genera Schizomycetum. Ann. Mycologie., Berlin. 11:546.
41. Williams, M.A. and S.C. Rittenberg. 1956. Microcyst formation and germination in Spirillum lunatum. Jour. Gen. Microbiol. 15:205-209.
42. _____. 1957. A taxonomic study of the genus Spirillum Ehrenberg. Internatl. Bull. Bact. Nomen. and Tax. 7:49-110.

PLATE V

Reproduction of the photographs of G. Giesberger's species of Spirillum from Beitrage zur Kenntnis der Gattung Spirillum Ehbg., 1936. By permission of Dr. G. Giesberger.

Figure 7

1. Spirillum serpens (Müller) Winter.
2. Spirillum serpens Flagella.
3. Spirillum serpens Volutin.

Figure 8

4. Spirillum serpens Colony on agar.
5. Spirillum itersonii Giesberger.
6. Spirillum itersonii Colony.

Figure 9

7. Spirillum tenue (Müller) Ehrenberg.
8. Spirillum undula (Müller) Ehrenberg.

Figure 10

9. Spirillum kutscheri Migula.
10. Spirillum kutscheri Migula.

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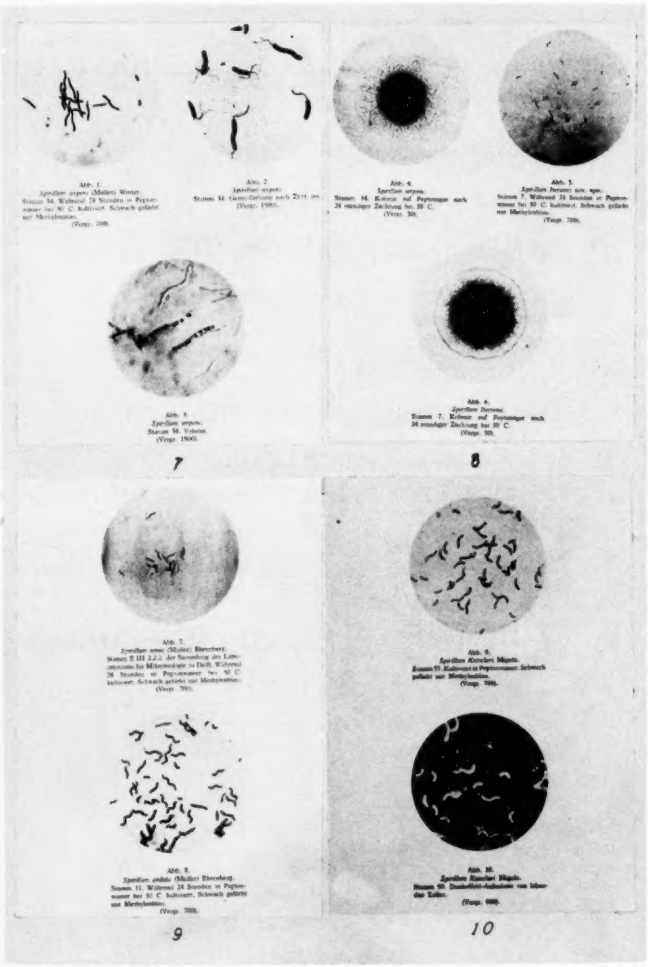

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PLATE VI

Figure 11

Reproductions of various drawings and photographs of Vibrio serpens and Spirillum serpens.

A. Vibrio serpens after Muller, 1786.

B. Vibrio serpens after Cohn, 1872.

C. Spirillum serpens after Migula, 1897.

D. Spirillum serpens after Giesberger, 1936.

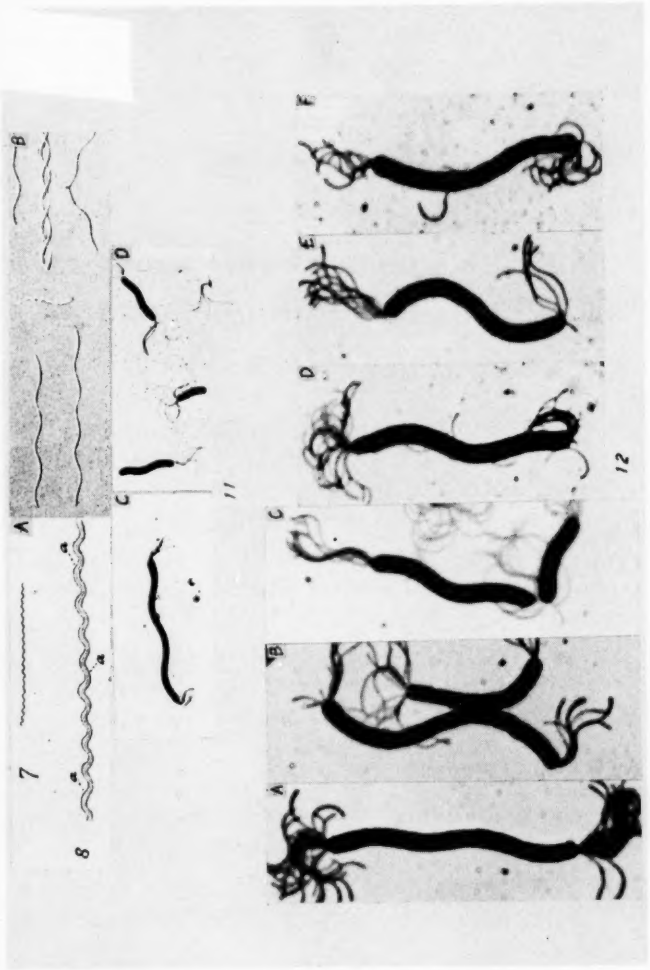
Figure 12

Flagellar stain photographs. (After Leifson)

A. Spirillum serpens Giesberger, 1936.
S. serpens var. serpens Williams and Rittenberg, 1957.

B. Spirillum serpens var. azotum Williams and Rittenberg, 1957.

C.,D.,E.,F. Morphotypes of Spirillum serpens Giesberger, 1936.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